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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 391

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Washington, D. C. PROFESSIONAL PAPER December 10, 1918

ACCURACY IN COMMERCIAL GRADING OF OPENED EGGS

By

M. K. JENKINS, Assistant Bacteriologist, and
NORMAN HENDRICKSON, Assistant Chemist,
Food Research Laboratory

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By M. K. JENKINS, *Assistant Bacteriologist*, and NORMAN HENDRICKSON, *Assistant Chemist, Food Research Laboratory.*

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INTRODUCTION.

The quality of liquid egg used in making frozen or dried egg products depends upon two factors: First, the character of the eggs entering the product; and, second, the cleanliness of preparation. Eggs, good and bad, as they appear before the candle and out of the shell, with their respective chemical and bacterial characteristics, have been discussed in Bulletin 51.[1] The precautions necessary to insure cleanliness when opening the eggs and collecting their contents to be frozen or dried have been discussed in Bulletin 224,[2] in which publication much attention is directed also to the character of the eggs used. During the progress of the work the question of the accuracy of grading eggs by sight, smell, and taste frequently arose. It was observed that samples made from comparatively high-grade stock sometimes had a higher bacterial content than could be accounted for on the basis of faulty manipulation. They seldom showed chemical evidence of decomposition. It was observed, also, that the lower the grade of the breaking-stock eggs and the more numerous the discards in the breaking room, the higher was the average bacterial count, even though every care was used by the breaker to eliminate unfit eggs. Apparently, then, there are some infected eggs among the cracked eggs, dirty eggs, and stale seconds, which so often go to the egg-breaking plant, which it is either quite impossible or very difficult to detect when grading out of the shell by ordinary means. The questions now to be considered are: What is the character of these eggs, how many bacteria do they contain, and how frequently do they occur?[1]

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[1] A Bacteriological and Chemical Study of Commercial Eggs in the Producing Districts of the Central West. U. S. Dept. Agr. Bul. 51, 77 p., 8 pl., 2 fig., July 20, 1914.

[2] A Study of the Preparation of Frozen and Dried Eggs in the Producing Section. U. S. Dept. Agr. Bul. 224, 99 p., 17 pl., 7 fig., Apr. 28, 1916.

PURPOSE, PLAN, AND EXTENT OF INVESTIGATION.

PURPOSE.

The purpose of the investigation was fourfold:

1. To obtain additional information regarding the bacteriology of individual eggs used in the preparation of frozen and dried eggs.

2. To determine the accuracy of the present methods of grading individual eggs.

3. To find the number and kinds of eggs containing bacteria not detected by the usual grading.

4. To determine the effect of eggs containing bacteria upon composite products as evidenced by the bacterial content and the amount of ammoniacal nitrogen present in the finished product.

PLAN.

The material for study consisted of breaking stock—that is, odd-sized eggs, dirty eggs, cracked eggs, shrunken eggs, and heated eggs. The samples were made up of approximately six dozen eggs each and were purchased in all but a few instances from commission houses located in a large eastern consuming center.

All of the eggs for the experiments were commercially candled by the regular candlers of the commission house, who aimed to reject as unfit for food purposes all eggs containing blood, either in the form of clots or blood rings, all eggs with either broken or adherent yolks, and all addled eggs, and to retain eggs with whole yolks freely moving in the white. Eggs showing signs of incubation prior to the appearance of the blood ring were not discarded.

On receipt at the laboratory each egg in the sample was numbered and described fully. The color, cleanliness, and soundness of the shell were noted. The eggs were recandled and the condition of the white and yolk observed. They were then opened aseptically and placed individually into sterile glass custard cups similar to those used in the cooperating egg-breaking plants for holding the eggs during grading. The cups were kept covered to prevent contamination from the air.

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[1] The work discussed in this bulletin was done under the direction of Dr. M. E. Pennington, to whom thanks are due for many valuable suggestions. A large part of the routine bacteriological work was done by Dr. E. Q. St. John and Dr. E. Witmer, and the chemical work was performed by E. L. Connolly.

In order that the grading might be uniform throughout the investigation and parallel the method followed in the cooperating egg-breaking plants, all of it was done by the same person, who was familiar with commercial procedures. Each egg was graded as good or bad, according to appearance and odor, and in case of doubt was graded also according to taste.

After each egg was graded, a portion was removed to be examined for the number of bacteria and for the presence or absence of members of the *B. coli* group.[1] All of the eggs graded as good were then mixed to form a composite sample, which was examined for the total number of bacteria, the number of organisms producing gas in lactose bile, the percentage of moisture, and the amount of ammoniacal nitrogen as determined by the Folin titration method.

After the egg had been thoroughly mixed, one cubic centimeter was withdrawn.[2] With this portion dilutions of 1 to 10, 1 to 100, and 1 to 1,000 were made with physiological salt solution. From the three dilutions plates were made with nutrient agar as the medium. One cc of the first dilution was transferred to a fermentation tube containing lactose bile. The plates were incubated at room temperature for 5 days and the fermentation tubes at 37° C. for 2 days. This procedure was followed in the examination of the individual egg. The composite samples were examined according to the methods described in Department Bulletin 51 (pp. 74 to 77). The number of bacteria in the individual eggs is expressed on the cubic-centimeter basis. As an egg which has been frozen for any length of time becomes so thick that it is not possible to deliver definite quantities accurately from a pipette, the portion of frozen egg to be examined was weighed and the results expressed on the gram basis. The two bases are comparable because the specific gravity of the egg after the white and yolk are mixed is practically unity.

EXTENT.

During the course of the study 2,052 individual breaking-stock eggs, representing 29 samples, which varied in size from 66 to 72 eggs, were studied according to the plan just outlined. The samples were procured at fairly regular intervals between May 23 and October 27, 1913, a period which covered the greater part of the egg-breaking season in the consuming center from which the eggs were chosen.

---

[1] The terms *B. coli*, *B. coli* group, and organisms or bacteria producing gas in lactose bile are used synonymously in this publication.

[2] For the purpose of this report, eggs which did not show the presence of bacteria in 1 cc have been considered sterile, since a smaller number of bacteria is negligible from the viewpoint of possible food contamination.

HISTORY AND BACTERIAL CONTENT OF SAMPLES.

HISTORY OF SAMPLES.

Most of the samples of breaking-stock eggs used for the investigation were procured from the current receipts of commission houses located in an eastern consuming center. In a few instances in the beginning of the season samples were purchased from grocery stores. Late in the season the samples consisted of breaking-stock eggs sorted from eggs coming from storage. The firms from whom most of the samples were obtained operated egg-breaking plants in addition to their wholesale business. Most of the eggs were produced either in the Middle Western States or in Virginia, and were shipped to the consuming center, after the weather had become warm, in refrigerator cars. The time occupied in making the haul varied from 3 to 12 days. The history of each sample is given in Table I.

Table I.—*History of samples.*

Sample No.	Shipped from—	Date shipped.	Date received at commission house.	In storage.	Out of storage.	Date examined.	Kind of eggs.
		1913.	1913.	1913.	1913.	1913.	
41142	Edinburg, Va.	May 17	May 20			May 23	Cracked eggs.
41143	Moorestown, N. J.		May 27			May 27	Fresh brown-shelled eggs.
41144	Edinburg, Va.	May 22	May 26			May 29	Dirty eggs.
41145	do					June 3	Seconds.
[1] 41146						June 10	Do.
41147						June 12	Grocery eggs.
41148						June 17	Do.
41149	Woodbine, Iowa.	June 10	June 18			June 19	Cracked eggs.
41161	Edinburg, Va.	June 12	June 16			June 20	Seconds and cracked eggs.
41164	Woodbine, Iowa.	June 16	June 23			June 24	Cracked eggs.
41167	Mount Jackson, Va.	June 14	June 24			June 26	Seconds.
41169	New Albany, Ind	June 12	June 21			June 27	Do.
41175	New York, N. Y.	July 7	July 9			July 10	Seconds and cracked eggs.
41178	Edinburg, Va.	July 8	July 11			July 16	Do.
41180	Logan, Iowa	July 7	July 18			July 21	Do.
41182	do	July 14	July 21			July 22	Do.
41185	Edinburg, Va.	July 15	July 18			July 23	Do.
41189	do	July 17	July 21			July 25	Do.
41192	do	July 19	July 24			July 29	Do.
41316	Woodbine, Iowa.	Aug. 7	Aug. 16			Aug. 18	Do.
41435	Edinburg, Va.	Sept. 4	Sept. 8			Sept. 10	Do.
41438	Owatonna, Minn.		Sept. 8,9			Sept. 11	Do.
[1] 41505						Sept. 19	Seconds, cracked, and dirty eggs.
41506	Edinburg, Va.	Sept. 20	Sept. 22			Sept. 25	Dirty and cracked eggs.
41509	Decatur, Ind., and Manitowoc, Wis.			July 21	Sept. 24	Sept. 26	Do.
41551	Bluffton, Ind.	July 19	July 23	July 23		Oct. 3	Seconds, cracked, and dirty eggs.
41645	Harrisonburg, Va	May 5	May 7	May 7	Oct. 14	Oct. 15	Do.
[1] 41598				Apr. 13	Oct. 13	Oct. 17	Do.
41645	Michigan	Apr. 15		Apr. 22	Oct. 25	Oct. 27	Do.

[1] Purchased at commission house; further history unknown.

NUMBER OF EGGS CONTAINING BACTERIA.

Only a few of the individual eggs examined contained appreciable numbers of bacteria. Two lots, Nos. 41192 and 41645, were exceptional in that nearly all the eggs comprising them harbored bacteria. Of the 2,052 eggs included in the 29 samples, 13.5 per cent, as computed from Table II, were found to contain more than 100 organisms per cc. The remaining 86.5 per cent contained less than 100 organisms per cc, that is, they were practically sterile. Only 3.3 per cent contained over 500,000 organisms per cc. The percentage of eggs containing *B. coli* (2.8 per cent) was considerably less than the total percentage of the eggs containing bacteria.

A very large percentage of the eggs comprising sample No. 41192 had both dirty and cracked shells. These eggs were laid in July when the weather was very hot. It is highly probable that bacterial penetration and development took place between the time of first assortment in the producing section and final receipt in the consuming center, as an interval of 10 days occurred between the date of shipping and that of grading in the commission house, during a portion of which period the eggs were without refrigeration. Had these eggs been utilized promptly in the first concentrating center, there is little doubt that only a few of them would have been found to contain bacteria. The results obtained in the case of these eggs show the importance of having eggs with defective shells opened as near the source of production as possible.

TABLE II.—*Variation in bacterial content of samples of individual eggs candled as good.*

Sample No.	Date of examination.	Number of eggs.	Number of bacteria per cc.													
			0 to 100.		101 to 1,000.		1,001 to 10,000.		10,001 to 50,000.		50,001 to 100,000.		100,001 to 500,000.		Over 500,000.	
			No. of eggs.	P.ct.	No. of eggs.	P.ct.	No. of eggs.	P.ct.	No. of eggs.	P.ct.	No. of eggs.	P.ct.	No. of eggs.	P.ct.	No. of eggs.	P.ct.
	1913.															
41142	May 23	72	71	98.6	1	1.4	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
41143	May 27	72	72	100.0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
41144	May 29	72	69	95.8	.....	.....	2	2.8	.....	.....	.....	.....	.....	.....	1	1.4
41145	June 3	70	70	100.0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
41146	June 10	71	67	94.4	1	1.4	1	1.4	.....	.....	.....	.....	.....	.....	2	2.8
41147	June 12	70	67	95.7	2	2.9	.....	.....	.....	.....	.....	.....	.....	.....	1	1.4
41148	June 17	72	71	98.6	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1	1.4
41149	June 19	70	54	77.1	5	7.1	2	2.9	.....	.....	.....	.....	3	4.3	6	8.6
41161	June 20	72	69	95.9	.....	.....	.....	.....	1	1.4	1	1.4	.....	.....	1	1.4
41164	June 24	69	67	97.1	1	1.5	.....	.....	.....	.....	.....	.....	.....	.....	1	1.5
41167	June 26	72	71	98.6	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1	1.4
41169	June 27	71	67	94.4	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	4	5.6
41175	July 10	70	61	87.1	3	4.3	1	1.4	3	4.3	.....	.....	.....	.....	2	2.9
41178	July 16	69	66	95.7	1	1.4	.....	.....	.....	.....	.....	.....	.....	.....	2	2.9
41180	July 21	70	57	81.4	7	10.0	.....	.....	1	1.4	.....	.....	.....	.....	5	7.1
41182	July 22	70	64	91.4	3	4.3	1	1.4	1	1.4	1	1.4	.....	.....	.....	.....
41185	July 23	71	67	94.4	2	2.8	1	1.4	.....	.....	.....	.....	.....	.....	1	1.4
41189	July 25	72	66	91.7	1	1.4	.....	.....	.....	.....	.....	.....	2	2.8	3	4.2
41192	July 29	66	.....	.....	4	6.1	11	16.6	14	21.2	9	13.6	21	31.8	7	10.6
41316	Aug. 18	70	63	90.0	3	4.3	2	2.8	.....	.....	.....	.....	.....	.....	2	2.9
41435	Sept. 10	70	62	88.6	1	1.4	1	1.4	1	1.4	.....	.....	.....	.....	5	7.1
41438	Sept. 11	71	64	90.1	2	2.8	.....	.....	.....	.....	.....	.....	1	1.4	4	5.6
41505	Sept. 19	72	63	87.5	1	1.4	.....	.....	1	1.4	1	1.4	.....	.....	6	8.3
41506	Sept. 25	72	64	88.9	1	1.4	1	1.4	2	2.8	1	1.4	.....	.....	3	4.2
41509	Sept. 26	71	66	93.0	2	2.8	.....	.....	.....	.....	.....	.....	.....	.....	3	4.2
41551	Oct. 3	72	63	87.5	7	9.7	2	2.8	.....	.....	.....	.....	.....	.....	.....	.....
41594	Oct. 15	71	63	88.7	4	5.6	.....	.....	.....	.....	1	1.4	.....	.....	3	4.2
41598	Oct. 17	72	56	77.8	13	18.1	1	1.4	1	1.4	.....	.....	1	1.4	.....	.....
41645	Oct. 27	70	14	20.0	11	15.7	19	27.1	11	15.7	6	8.5	4	5.7	5	7.1
Total		2,052	1,774	86.5	76	3.7	45	2.2	36	1.7	20	1.0	32	1.5	69	3.4

The eggs composing sample No. 41645 were low-grade seconds and cracked eggs sorted from April storage packed eggs. Although the bacterial findings in these eggs are extreme, they afford a good example of what happens when undergrade stock, particularly cracked eggs, is held in storage for several months. Other investigations confirm the bacterial findings in these grades of eggs.[1]

While the actual number of eggs in these two samples is small, they represent grades of eggs which come with more or less frequency to all egg-breaking plants. It is evident that it is not possible to prepare from them a uniformly high-grade product.

The results obtained from the examination of these eggs, as pictured graphically in figure 1, show the condition in which the eggs under observation, which had been candled as fit for food purposes, would have reached the consumer had they been sold in the shell. In other words they show the limitations of candling as the only method for determining the condition of market eggs. It will appear subsequently to what extent the grading of eggs out of the shell is of assistance in the separation of sterile eggs from nonsterile eggs.

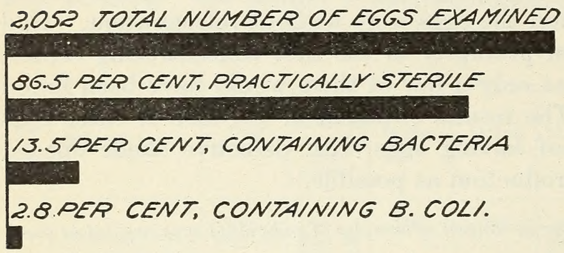

FIG. 1.—Results of bacteriological examination of candled breaking stock.

EFFECT OF CONDITION OF SHELL UPON BACTERIAL CONTENT OF EGG.

DESCRIPTION OF THE EGG SHELL.

The contents of an egg is protected by a shell and two membranes. The shell, which is composed largely of lime salts, is porous and is coated with a mucilaginous material which gives the bloom characteristic of newly laid eggs. The two elastic membranes which line the shell consist of microscopic fibers very closely interlaced. The outer tissue is much heavier than the inner. The two separate at the large end of the egg and form the upper and lower walls of the air cell. Nature has thus provided a protective porous covering through which the respiration of the chick, during its embryonic development, may proceed. If the shell is not cracked it offers a very effective barrier against mold and bacterial penetration. If it is cracked, however, bacteria can more readily penetrate the two membranes. Egg handlers are familiar with the growth of mold in the crevices of a cracked shell.[2] In a large number of examinations[3] of eggs containing molds, bacteria were found to be present in almost all instances, usually in large numbers. The contents of leaking eggs, that is, eggs in which the shell and both membranes are broken, may become contaminated directly.

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[1] Unpublished results. [2] U. S. Dept. Agr. Bul. 51, pl. VI. [3] U. S. Dept. Agr. Bul. 51, pp. 33–48.

It has been stated by Kossowicz[1] that the shells of stale eggs offer less resistance to bacterial and mold invasion than do those of fresh eggs. Even the shells of clean eggs frequently harbor many bacteria and also *B. coli.*[2]

Experiments have shown that bacteria and molds can penetrate an unbroken shell if it is in a moist condition. Water removes the mucilaginous coating naturally present on the shells and renders the fibrous membrane pervious to organisms. Hen feces and the contents of broken eggs when damp attach themselves to the shell. The dirt then becomes the carrier of the bacteria and the moisture presents the mechanical means necessary for their penetration.

In the second report[3] of this series, a general survey of the literature on bacteria in perfectly fresh eggs was given. Since this bulletin was published, Rettger[4] has discussed the results of the bacteriological examination of 20,000 newly laid eggs. His findings corroborate those of previous investigators, namely, that, with but few exceptions, strictly fresh eggs are sterile; and those which do contain bacteria have them only in small numbers. These bacteria are too few to affect the use of fresh eggs for food, but their presence or absence determines the ideal for eggs. The maintenance of low bacterial contents in eggs and egg products, therefore, is one index of the efficiency of egg-handling operations.

Many examples of eggs with high bacterial content are given in Department Bulletin 51. It is interesting to note that in those eggs in which both the white and yolk were examined, the number of bacteria was markedly greater in the white than in the yolk, a condition indicative of bacterial penetration from the exterior.

EGGS WITH SOUND, CRACKED, AND LEAKING SHELLS.

As a large percentage of the breaking stock of the cooperating egg-breaking plants consisted of eggs with defective shells, a detailed description was made of the condition of the shell of each egg in the 29 experimental samples examined in order to determine the effect of a dirty or damaged shell upon the condition of the contents. The results of this study are given in Table III and in figure 2.

The possibility of bacterial penetration increases with the amount of damage to the shell. The percentage of eggs containing bacteria was as follows: 8.7 per cent of eggs with sound shells, 18.6 per cent of eggs with cracked shells, and 30.7 per cent of eggs with leaking shells. (Table III, Part I.) The percentage of eggs containing *B. coli* was found also to be dependent upon the condition of the shell (Table III, Part III).

---

[1] Kossowicz, Alexander. Die Zersetzung und Haltbarmachung der Eier, pp. 42–54. Wiesbaden, 1913.

[2] Bacteriological Studies on Eggs. Kansas State Agr. Col. Exp. Sta., Bul. 180. 1911.

[3] U. S. Dept. Agr. Bul. 51, pp. 3, 4. 1914.

[4] Centbl. Bakt., [etc.] 2 Abt., 39 (1914), 611–624.

The number of bacteria in the eggs which contained organisms varied widely for the three groups, as can be seen from Part II of Table III. This is what would be expected, because after bacteria have once entered an egg the number present depends upon conditions favoring growth, such as warm temperatures.

These data substantiate the popular belief that organisms may penetrate eggs with sound shells if unfavorable conditions, such as filth, moisture, and high temperatures, are incurred during marketing, but not to such an extent as they penetrate cracked shells. The chance of contamination is greater in the case of leaking eggs, owing to exposure of the contents.

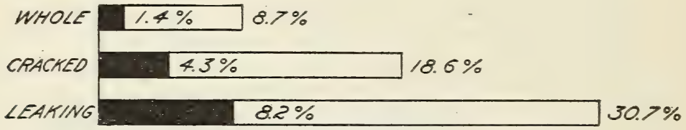

FIG. 2.—Relation of bacteria to soundness of shell. Total bar = per cent containing bacteria. Black portion of bar = per cent containing organisms fermenting lactose bile.

TABLE III.—*Relation of bacteria in eggs to soundness of shell.*

I. EGGS CONTAINING BACTERIA.

Description of shell.	Number examined.	Number positive.	Per cent positive.
Whole	[1] 1,167	101	8.7
Cracked	784	146	18.6
Leaking	101	31	30.7
Total	2,052	278	13.5

[1] 29 blind checks, 2 of which (6.9 per cent) contained bacteria, are included in this number.

II. VARIATION IN BACTERIAL CONTENT OF EGGS CONTAINING BACTERIA.

Description of shell.	Number of bacteria per cc. 101 to 1,000.		1,001 to 10,000.		10,001 to 50,000.		50,001 to 100,000.		100,001 to 500,000.		Over 500,000.		Total number of eggs.
	Number eggs.	Per cent.	Number eggs.	Per cent.	Number eggs.	Per cent.	Number eggs.	Per cent.	Number eggs.	Per cent.	Number eggs.	Per cent.	
Whole	33	32.7	15	14.8	8	7.9	9	8.9	7	6.9	29	28.7	101
Cracked	35	24.0	24	16.3	25	17.1	10	6.8	20	13.7	32	21.9	146
Leaking	8	25.8	6	19.4	3	9.7	1	3.2	5	16.1	8	25.8	31
Total	76	27.4	45	16.2	36	12.9	20	7.2	32	11.5	69	24.8	278

III. EGGS CONTAINING ORGANISMS FERMENTING LACTOSE BILE.

Description of shell.	Number examined.	Number positive.	Per cent positive.
Whole	1,132	6	1.4
Cracked	751	32	4.3
Leaking	97	8	8.2
Total	1,980	56	2.8

CLEANLINESS AND SOUNDNESS OF SHELL.

As would be expected, the percentage of eggs containing bacteria is less in eggs with clean shells than in those with dirty shells, and the percentage of eggs with bacteria becomes greater as the damage to the shell increases. The percentage of the eggs which contained bacteria, as shown by Table IV, Part I, and by figure 3, was as follows: 7.5 per cent for clean whole eggs, 10.8 per cent for dirty whole eggs, 17.2 per cent for clean cracked eggs, 23.2 per cent for dirty cracked eggs, 28.2 per cent for clean leakers, and 39.1 per cent for dirty leaking eggs.

The number of eggs harboring *B. coli* was also affected by the condition of the shell. Inasmuch as the number of leaking eggs examined for *B. coli* was too few to warrant conclusions, the few results obtained from them are grouped with the cracked eggs. Table IV, Part III, shows that 0.3 per cent (no more than the probable chance of experimental error) of the clean whole eggs, 3.4 per cent of the dirty whole eggs, 3.7 per cent of the clean, cracked, and leaking eggs, and 7.8 per cent of the dirty, cracked, and leaking eggs, contained these gas-producing bacteria.

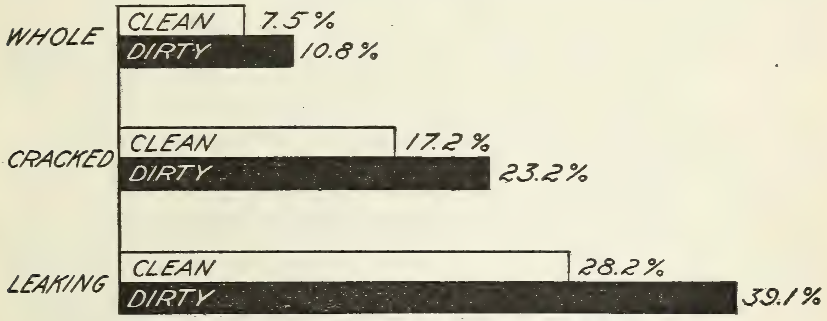

FIG. 3.—Relation of bacteria to soundness and cleanliness of shell.

It can be seen from Table IV that the percentage of eggs containing *B. coli* is practically the same for the clean, cracked, and leaking eggs as for the dirty eggs with whole shells. This is explained by the large number of these organisms in the hen feces, the most prevalent form of filth on hen's eggs.

The marked contrast between the bacterial content of eggs with clean sound shells and those with cracked or dirty shells, or both, emphasizes the care which farmers and carriers should exercise to prevent the soiling and damaging of shells.

The methods followed at present by the more progressive and careful egg handlers show that considerable care is being taken in the handling of eggs. When eggs are being prepared for cold storage, packers aim to remove by inspection and by clicking all cracked and leaking eggs, because it has been observed that such eggs become moldy or otherwise deteriorate much more quickly than eggs with sound shells. For the same reason dirty eggs are not held in storage in very large quantities, nor for a very long period, although the deterioration of such eggs is not so rapid as is the case with cracked and leaking eggs. The observations of practical egg handlers, as well as laboratory results, show clearly the necessity for breaking dirty and cracked eggs as promptly as possible and preserving them in a frozen or dried form.

TABLE IV.—*Relation of bacteria in eggs to cleanliness and soundness of shell.*

I. EGGS CONTAINING BACTERIA.

Soundness of shell.	Cleanliness of shell.	Number examined.	Number positive.	Per cent positive.
Whole	Clean	760	57	7.5
Do	Dirty	407	44	10.8
Cracked	Clean	599	103	17.2
Do	Dirty	185	43	23.2
Leaking	Clean	78	22	28.2
Do	Dirty	23	9	39.1
Total		2,052	278	13.5

II. VARIATION IN BACTERIAL COUNT OF EGGS CONTAINING BACTERIA.

Description of shell.	Number of bacteria per cc.												Total number of eggs.
	101 to 1,000.		1,001 to 10,000.		10,001 to 50,000.		50,001 to 100,000.		100,001 to 500,000.		Over 500,000.		
	Number of eggs.	Per cent.	Number of eggs.	Per cent.	Number of eggs.	Per cent.	Number of eggs.	Per cent.	Number of eggs.	Per cent.	Number of eggs.	Per cent.	
Whole and clean	22	38.8	10	17.5	3	5.2	3	5.2	4	7.0	15	26.3	57
Whole and dirty	11	25.0	5	11.4	5	11.4	6	13.6	3	6.8	14	31.8	44
Cracked and clean	24	23.3	21	20.4	19	18.4	4	3.8	13	12.6	22	21.4	103
Cracked and dirty	11	25.6	3	6.9	6	13.9	6	13.9	7	16.3	10	23.3	43
Leaking and clean	6	27.3	5	22.7	2	9.1	1	4.5	3	13.6	5	22.7	22
Leaking and dirty	2	22.2	1	11.1	1	11.1			2	22.3	3	33.3	9
Total	76		45		36		20		32		69		278

III. EGGS CONTAINING ORGANISMS FERMENTING LACTOSE BILE.

Soundness of shell.	Cleanliness of shell.	Number examined.	Number positive.	Per cent positive.
Whole	Clean	727	2	0.3
Do	Dirty	405	14	3.4
Cracked and leaking	Clean	645	24	3.7
Do	Dirty	203	16	7.8
Total		1,980	56	2.8

RELATION BETWEEN THE NUMBER OF BACTERIA AND THE PHYSICAL CONDITION OF THE EGG CONTENTS.

CONDITION OF YOLK.

The physical condition of an egg indicates to a large extent its state of preservation. The white of a strictly fresh egg is stiff and the yolk stands up firmly, as can be seen very clearly from Plate I.[1] As the egg ages, the white becomes thinner, the yolk flatter, and the vitelline membrane weaker. When a stale egg is opened, the vitelline membrane frequently is ruptured and the contents of the yolk flows into and through the white, as illustrated in Plate III.[2] This type of egg is commonly called a "weak egg" or a "soft egg," and occurs most frequently in summer weather. Fertile eggs showing advanced hatch spots almost invariably contain weak yolks.

Eggs produced in the spring of the year generally have a firm consistency; that is, both white and yolk have the viscosity of the fresh egg. Occasionally it happens that a portion of the contents of the yolk has seeped through the vitelline membrane into the white in sufficient amount to give it a yellowish tinge. (See Plate II.) Although this condition prevails before the egg is opened, it is rarely detected by candling.

Because of their physical condition neither "soft eggs" nor eggs with incipient seeping yolks can be separated satisfactorily into white and yolk. These eggs appear to have whole yolks before the candle. If, on breaking, their odor is normal and the white not green, they may be considered suitable for baking and cooking. When the seepage of the yolk is so advanced that it extends entirely through the white, the egg should be discarded. Such an egg has the appearance of a mixed rot before the candle.[3]

Further deterioration in the shell of a "weak egg" or "soft egg" results in the final rupture of the vitelline membrane and a partial mixing of white and yolk. This egg, which is one type of a mixed rot, is illustrated in Plate IV. The physical mixing of the white and yolk progresses until the egg becomes what is known as an addled egg or a white rot. Frequently, eggs containing blood rings or adherent yolks pass through the different stages of deterioration until they become addled eggs.

It was found that the percentage of eggs with bacteria increased with the physical breaking down of the yolk, as shown by Table V. The percentage of eggs containing bacteria was as follows: 10.6 for eggs with whole yolks, 22.7 for soft eggs, and 43.5 for eggs with partially addled contents or with yolks adherent to the shell. The results of the examination of eggs with partially or entirely deteriorated yolks harmonize with those obtained in previous investigations.[1]

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[1] Reprint from U. S. Dept. Agr. Bul. 51, pl. I, and U. S. Dept. Agr. Bul. 224, pl. XVII.

[2] Reprint from U. S. Dept. Agr. Bul. 224, pl. XIV.

[3] U. S. Dept. Agr. Bul. 224, pl. XVI.

These findings also show that a very large percentage of "soft eggs" consisted of sterile eggs. Consequently, the first stages of deterioration in the yolks of such eggs in most instances can not be ascribed to bacteria.

Deterioration in eggs that is not due to the presence of bacteria may be the result either of the action of native enzyms[2] or of osmosis[3] of water from the white to the yolk, thereby causing the vitelline membrane to stretch and become weakened. It was the aim of the candlers at the commission houses to exclude eggs with adherent yolks or addled contents, but through error in candling a few of such eggs were present in the samples.

Part III of Table V shows that a larger proportion of the eggs with broken yolks contained bacteria than did those with whole yolks.

TABLE V.—*Relation of bacteria in eggs to condition of yolk.*

I. EGGS CONTAINING BACTERIA.

Description of yolk.	Number examined.	Number positive.	Per cent positive.
Whole	1,588	168	10.6
Broken	441	100	22.7
Adherent or addled	23	10	43.5
Total	2,052	278	13.5

II. VARIATION IN BACTERIAL CONTENT OF EGGS CONTAINING BACTERIA.

Description of yolk.	Number of bacteria per cc.												Total number of eggs.
	101 to 1,000.		1,001 to 10,000.		10,001 to 50,000.		50,001 to 100,000.		100,001 to 500,000.		Over 500,000.		
	Number of eggs.	Per cent.	Number of eggs.	Per cent.	Number of eggs.	Per cent.	Number of eggs.	Per cent.	Number of eggs.	Per cent.	Number of eggs.	Per cent.	
Whole	54	32.1	28	16.7	20	11.9	11	6.5	19	11.3	36	21.4	168
Broken	21	21.0	15	15.0	16	16.0	8	8.0	12	12.0	28	28.0	100
Adherent or addled	1	10.0	2	20.0	......	......	1	10.0	1	10.0	5	50.0	10
Total	76	......	45	......	36	......	20	......	32	......	69	......	278

III. EGGS CONTAINING ORGANISMS FERMENTING LACTOSE BILE.

Description of yolk.	Number examined.	Number positive.	Per cent positive.
Whole	1,527	30	2.0
Broken	431	21	4.9
Adherent or addled	22	5	22.8
Total	1,980	56	2.8

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[1] U. S. Dept. Agr. Bul. 51, pp. 29, 30, 53, 54.

[2] U. S. Dept. Agr., Bureau of Chemistry Cir., 104, pp. 4, 5.

[3] U. S. Dept. Agr., Bureau of Chemistry Cir., 83, p. 3.

POSITION OF YOLK.

When viewed before the candle the yolk of a perfectly fresh egg is found to be located slightly above the meridian and is symmetrical with the long axis of the egg. It is indistinct in outline and moves very sluggishly as the egg is turned. As the egg ages the yolk apparently becomes more opaque and may settle against the lowest part of the shell.

Of all the eggs studied 1,795, or 87.5 per cent, were eggs with free yolks; 248, or 12.1 per cent, eggs with yolks settled close to the shell, but not adhering; and 9, or 0.4 per cent, eggs in which the yolks were either addled or adherent to the shell. Fewer eggs with adherent yolks or addled contents are listed in Table VI, which gives the results of examination of eggs graded by the candling method, than are listed in Table V, where the eggs were graded out of the shell. The reason for this is that eggs with slightly adherent yolks are often difficult to detect by candling, especially if the shell is brown.

These results confirm earlier studies [1] of similar eggs, in that they show that a settled yolk is not in itself an indication that the egg contains bacteria.

TABLE VI.—*Relation of bacteria in eggs to position of yolk.*

I. EGGS CONTAINING BACTERIA.

Position of yolk.	Number examined.	Number positive.	Per cent positive.
Free moving	1,795	241	13.4
Settled	248	32	12.9
Addled or adherent	9	5	55.5
Total	2,052	278	13.5

II. VARIATION IN BACTERIAL CONTENT OF EGGS CONTAINING BACTERIA.

Position of yolk.	Number of bacteria per cc.												Total number of eggs.
	101 to 1,000.		1,001 to 10,000.		10,001 to 50,000.		50,001 to 100,000.		100,001 to 500,000.		Over 500,000.		
	Number of eggs.	Per cent.	Number of eggs.	Per cent.	Number of eggs.	Per cent.	Number of eggs.	Per cent.	Number of eggs.	Per cent.	Number of eggs.	Per cent.	
Free moving	65	27.0	44	18.3	31	12.9	19	7.8	29	12.0	53	22.0	241
Settled	10	31.2	......	......	5	15.6	1	3.1	3	9.4	13	40.6	32
Addled or adherent	1	20.0	1	20.0	......	......	......	......	......	......	3	60.0	5
Total	76	......	45	......	36	......	20	......	32	......	69	......	278

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[1] U. S. Dept. Agr. Bul. 51, pp. 12, 30, 31.

TABLE VI.—*Relation of bacteria in eggs to position of yolk*—Continued.

III. EGGS CONTAINING ORGANISMS FERMENTING LACTOSE BILE.

Position of yolk.	Number examined.	Number positive.	Per cent positive.
Free moving	1,735	48	2.76
Settled	236	7	2.97
Addled or adherent	9	1	11.11
Total	1,980	56	2.7

DESCRIPTIONS AND BACTERIAL COUNTS OF EGGS GRADED OUT OF THE SHELL.

The fitness for food purposes of eggs sold in the shell is determined in the industry principally by candling. In addition to this examination, the progressive concerns which are preparing frozen and desiccated eggs grade each egg very carefully out of the shell according to its odor and appearance. Practically all of the cooperating houses used clear, uncolored glass cups in examining the eggs to facilitate grading, as the physical condition of an egg is seen more easily in a transparent than in an opaque container. Many eggs with light green whites are not detected in a metal cup because the container masks the color.

The system of grading worked out in the cooperating plants was used for the grading of the eggs when removed from the shell. An egg in which the yolk was whole, the albumen clear, and the odor normal was graded as good. If the yolk appeared whole before the candle but broke when dropped into the cup and the odor was good, the egg was graded as fit for food purposes. Any egg in which the yolk had so deteriorated that it was materially mixed with the white was discarded, even though there was no odor, as were also all addled eggs, the advanced stage of this type of egg. Eggs with heavily mottled yolks were graded as bad. (See Plate II.) All eggs in which the yolk clung to the shell, even to a slight degree, all eggs with green whites, and eggs containing diffuse blood or embryos showing blood rings were rejected. Eggs with an unpleasant odor, for example, musty eggs, sour eggs, and very strong eggs—eggs in which the natural odor of the egg is increased—were classed as bad. The descriptions and bacterial findings in the case of a typical lot of individual eggs are given in Table VII.

Of the eggs in the experimental samples which had been passed by the candlers as edible, 171, or 8.3 per cent, were classed as bad when graded out of the shell by appearance or odor. Had these inedible eggs been sold in the shell their condition would not have been seen until they were broken by the consumer. They would be eliminated by the trained breaker from frozen products.

TABLE VII.—*Descriptions and bacterial findings of a representative lot of individual eggs.*

[Sample No. 41149.]

No.	Description of shell.			Condition before the candle.			Condition out of the shell.		Number of organisms per cc on nutrient agar.	*B. coli* present in 1 cc of egg.
	Condition.	Color.	Degree of cleanliness.	Shrinkage.	White.	Yolk.	Yolk.	Odor.		
1	Whole	White	Badly stained	Marked	Thick	Whole	Whole	Good	0	0
2	Cracked	do	Stained with egg	Slight	do	do	Broken	do	0	0
3	Whole	do	Clean	do	do	Whole, tendency to settle	do	do	0	0
4	Cracked	do	do	Marked	Thin	Whole	do	do	0	0
5	do	do	do	Air cell invisible before candle.	Thick	do	Whole	do	0	0
6	do	do	do	Marked	Thin	do	do	do	0	0
7	Whole	do	do	Slight	Thick	do	do	do	0	0
8	Cracked	Brown	do	Marked	do	do	Whole, enlarged hatch spot.	do	0	0
9	do	White	do	do	do	do	Whole	Strong	280,000	+
10	Leaking	Brown	do	Very marked	do	do	do	Good	0	0
11	Whole	White	do	Slight	Thin	do	do	do	0	0
12	do	do	Stained with egg	do	do	do	do	Strong	0	0
13	do	Brown	Clean	do	Thick	do	do	Good	0	0
14	Leaking	do	Very dirty	Very marked	do	do	do	do	140,000	0
15	do	do	Clean	do	Thin	do	Broken	Strong	610	0
16	Whole	do	do	Marked	do	Whole, floats near shell	Whole	Good	0	0
17	Leaking	do	do	Very marked	do	Whole	do	do	0	0
18	Cracked	do	do	do	do	do	do	do	0	0
19	do	do	do	Slight	do	do	do	do	0	0
20	do	do	do	do	do	Whole, settled	do	do	0	0
21	do	White	do	Marked	do	do	do	do	0	0
22	Whole	Brown	Stained	Slight	do	Whole	Broken	do	0	0
23	Leaking	do	Clean	Marked	do	do	Whole	do	0	0
24	Whole	do	Stained	Slight	do	do	do	do	0	0
25	do	White	do	do	do	do	do	do	0	0
26	do	Brown	Clean	Marked	do	do	do	do	0	0
27	Cracked	White	do	Very marked	do	do	do	do	60	0
28	Leaking	Brown	Smeared with egg	Slight	do	do	do	do	290	0
29	do	White	Clean	Very marked	do	do	do	do	0	0
30	Cracked	Brown	do	Slight	do	do	do	Strong	0	0
31	do	do	Dirty	Marked	do	do	do	Good	0	0
32	Whole	do	do	do	do	do	do	do	0	0
33	Cracked	White	do	Very marked	do	do	do	do	0	0
34	do	do	Clean	do	do	do	do	do	6,400	0

TABLE VII.—*Descriptions and bacterial findings of a representative lot of individual eggs*—Continued.

No.	Description of shell.			Condition before the candle.			Condition out of the shell.		Number of organisms per cc on nutrient agar.	*B. coli* present in 1 cc of egg.
	Condition.	Color.	Degree of cleanliness.	Shrinkage.	White.	Yolk.	Yolk.	Odor.		
[1]35	Cracked	White	Clean	Very marked	Light green	Whole	Broken	Good	[2]	+
[1]36	do	do	do	Marked	White and yolk nearly mixed.		White and yolk partially mixed.	do	[2]	+
37	do	do	do	do	Thin	Whole	Whole	do	0	0
38	do	do	do	do	do	do	do	do	0	0
[1]39	do	do	Stained	Very marked	do	do	Small blood ring	do	0	0
40	Leaking	do	Slightly dirty	do	do	do	Broken	Strong	0	0
41	do	do	Stained	do	do	do	Whole	Good	0	0
42	Cracked	do	Clean	Marked	do	do	do	do	0	0
43	Leaking	do	do	do	do	do	do	do	130,000	0
44	Cracked	do	do	Slight	do	do	do	do	500	0
45	do	do	do	do	do	do	Broken	do	0	0
46	do	do	do	Marked	do	do	Whole	do	0	0
47	do	do	Stained	Slight	do	Whole, settled	do	Slight, abnormal	[2]	+
48	do	do	Clean	do	do	Whole	Broken	Good	0	0
49	do	do	do	Marked	do	do	Whole	Strong	0	0
50	do	do	Stained	do	do	do	do	Good	0	0
51	Whole	do	Clean	do	do	do	do	do	0	0
52	do	do	do	Slight	do	do	do	do	0	0
53	Cracked	do	do	Marked	do	do	do	do	0	0
54	do	do	do	Slight	do	do	do	do	0	0
55	Leaking	do	do	Marked	do	do	do	do	0	0
56	Cracked	do	Stained	Slight	do	do	Broken	Strong	[2]	+
57	do	do	Clean	do	do	do	Whole	Good	0	0
58	do	do	do	do	do	do	do	Strong	0	0
59	do	do	Stained	Very marked	do	do	do	Good	0	0
60	Whole	do	Clean	Marked	do	do	do	do	[2]	+
61	do	Brown	do	Slight	do	do	do	do	0	0
62	Cracked	do	do	Marked	do	do	do	do	[2]	0
63	Whole	do	do	Slight	do	do	do	do	0	0
64	Cracked	White	do	do	do	do	do	do	0	0
65	do	do	Stained	do	do	do	Broken	Strong	0	0
66	Whole	do	Clean	Marked	do	do	do	do	0	0
67	Cracked	Brown	do	do	do	do	Whole	do	0	0
68	Whole	do	do	do	do	do	Broken	Good	0	0
69	Cracked	White	Stained	Slight	do	do	Whole	do	4,100	+
70	do	do	Clean	do	do	do	do	do	500	0

[1] Rejected as unfit for food purposes.

[2] Innumerable in dilution of 1 to 1,000.

TABLE VIII.—*Bacterial findings in eggs graded out of the shell.*

I. EGGS CONTAINING BACTERIA.

Grade.	Number examined.	Number positive.	Per cent positive.
Good	1,881	225	12.0
Bad	171	53	31.0
Total	2,052	278	13.5

II. EGGS CONTAINING ORGANISMS FERMENTING LACTOSE BILE.

Grade.	Number examined.	Number positive.	Per cent positive.
Good	1,809	40	2.2
Bad	171	16	9.4
Total	1,980	56	2.8

TABLE IX.—*Eggs containing bacteria and graded out of the shell as good.*

Sample No.	Number of bacteria per cc.												Total number of eggs.
	101 to 1,000.		1,001 to 10,000.		10,001 to 50,000.		50,001 to 100,000.		100,001 to 500,000.		Over 500,000.		
	Number of eggs.	Per cent.	Number of eggs.	Per cent.	Number of eggs.	Per cent.	Number of eggs.	Per cent.	Number of eggs.	Per cent.	Number of eggs.	Per cent.	
41142													0
41143													0
41144			1	100.0									1
41145													0
41146	1	50.0	1	50.0									2
41147	1	100.0											1
41148											1	100.0	1
41149	5	35.7	2	14.3					3	21.4	4	28.6	14
41161													0
41164	1	50.0									1	50.0	2
41167											1	100.0	1
41169											3	100.0	3
41175	3	37.5	1	12.5	2	25.0					2	25.0	8
41178	1	50.0									1	50.0	2
41180	7	70.0			1	10.0					2	20.0	10
41182	3	50.0	1	16.7	1	16.7	1	16.6					6
41185	2	66.7									1	33.3	3
41189	1	33.3									2	66.7	3
41192	4	7.3	11	20.0	14	25.4	8	14.6	13	23.6	5	9.1	55
41316	3	60.0	1	20.0							1	20.0	5
41435	1	20.0	1	20.0	1	20.0					2	40.0	5
41438	1	20.0							1	20.0	3	60.0	5
41505	1	20.0			1	20.0	1	20.0			2	40.0	5
41506	1	16.7	1	16.7	2	33.3	1	16.7			1	16.6	6
41509	2	50.0									2	50.0	4
41551	7	77.8	2	22.2									9
41594	4	57.1					1	14.3			2	28.6	7
41598	12	80.0	1	6.7	1	6.7			1	6.6			15
41645	11	21.2	19	36.5	10	19.2	6	11.5	4	7.7	2	3.9	52
Total	72	32.0	42	18.6	33	14.7	18	8.0	22	9.8	38	16.9	225

A bacteriological examination of the eggs graded out of the shell as edible showed that 12 per cent contained bacteria and 2.2 per cent *B. coli.* (See Table VIII.) The bacterial content of the great majority of the individual eggs included in the edible group, however, was low, as may be seen from Table IX. The variation in the counts of the eggs containing bacteria was as follows: 65.3 per cent were under 50,000; 16.9 per cent were over 500,000; and the remainder were between these two limits.

Of the total number of eggs which had been graded by the candle as edible, 69, or 3.4 per cent, were found to contain over 500,000 organisms per gram. (See Table II.) Nearly half, or 44.9 per cent, of these eggs, as computed from Tables II, IX, and XIII, were detected when graded out of the shell and eliminated from the composite samples. The remaining 55.1 per cent did not show either by appearance or odor that they were infected, and would have been used by egg breakers. A record of the appearance of each of these infected eggs is given in Table X.

EFFECT OF CONTAMINATED EGGS UPON COMPOSITE PRODUCTS.

The bacterial contents of the composite samples prepared from the eggs graded as good were in proportion to the degree of contamination of the eggs constituting them. The percentage of eggs containing bacteria in liquid mixtures composed of 69 to 72 eggs varied from 0 to 21.1 per cent, except in two samples which showed 73.2 per cent and 100 per cent. These samples represent lots 41192 and 41645 already discussed as exceptions on pages 4 and 5. The bacterial counts of the composite samples varied from 0, where all eggs were sterile, to 14,000,000, where the percentage of eggs with bacteria reached 81.3 per cent. (See Table XI.)

The percentage of eggs containing *B. coli* varied from 0 to 41.8 per cent in the different composite samples. The number of *B. coli* contributed to the composite product by the individual eggs varied from 0 to 500,000 per gram.

The percentage of ammoniacal nitrogen in the 29 lots of eggs was practically the same as that found in the commercial samples of frozen eggs. (Tables XI and XII.)

A survey of the bacterial counts given in Table XI shows decided similarity to those obtained in samples from the plants which have been cooperating in this investigation (see Table XII), and which have put into practical application the information obtained in the laboratory. Apparently certain eggs the condition of which can not now be detected by the senses are carriers of bacteria. However, it is very seldom that such eggs cause in the composite sample a bacterial count of more than a few millions. There is an agreement, also, between the number of *B. coli* in the commercial samples of well-handled eggs and the number found in the samples reported in this investigation.

In the cooperating plants the eggs were handled in refrigerated rooms, broken according to a routine involving strict cleanliness, and graded in accordance with the best available information. Faulty grading of the breaking stock either during candling or breaking may result in serious bacterial contamination of the product.

TABLE X.—*Description of individual eggs with bacterial counts of over 500,000 per gram.*

[Graded out of the shell as good.]

Sample No.	Egg No.	Description of shell.			Condition before the candle.		Condition out of the shell.		
		Condition.	Color.	Degree of cleanliness.	Shrinkage.	Yolk.	White.	Yolk.	Odor.
41148	43	Whole	Dark brown	Clean	Marked	Tendency to settle	Thin	Whole, with dark areas	Good.
41149	47	Cracked	White	Stained	Slight	Settled	do	Whole	Slightly abnormal.
41149	56	do	do	do	do	Normal	do	Broken	Strong.
41149	60	Whole	do	Clean	Marked	do	do	Whole	Good.
41149	62	do	Brown	do	do	do	do	do	Do.
41164	61	Leaking	White	do	do	do	do	Whole, with dark areas	Strong.
41167	44	Whole	Brown	do	do	do	Thin, turbid	Whole	Do.
41169	6	do	White	Dirty	do	Floats near shell	Thin	do	Good.
41169	67	do	Brown	Stained	do	Medium position	do	Large hatch spot	Do.
41169	71	do	White	Clean	do	Normal	do	Whole, with dark areas	Do.
41175	28	do	Brown	Dirty	Slight	Medium position	do	Broken	Strong.
41175	43	do	White	do	Marked	Normal	do	do	Good.
41178	50	Cracked	do	Clean	do	Below meridian line	do	Whole, with dark areas	Slightly abnormal.
41180	9	do	do	Dirty	do	Medium position	do	Flat	Strong.
41180	32	Leaking	do	Clean	do	Below meridian line	do	Normal	Good.
41185	45	Whole	do	Washed	do	Weak	do	Badly broken	Do.
41189	3	Porous	Brown	Clean	do	Medium position	do	Normal	Do.
41189	52	Cracked	do	do	Slight	Settled	do	do	Do.
41192	2	do	do	do	Marked	Normal	do	Broken	Do.
41192	4	Leaking	White	do	do	do	do	Normal	Do.
41192	17	Whole	do	Dirty	(1)	Below meridian line	do	do	Do.
41192	62	Cracked	do	do	Slight	Settled	do	Broken	Do.
41192	67	do	Brown	do	do	Normal	do	do	Do.
41316	55	Leaking	do	Clean	do	do	do	do	Do.
41435	23	Cracked	White	do	Marked	Settled	do	Broken and wrinkled	Doubtful sour.
41435	35	do	do	Stained	Slight	Below meridian line	do	Broken	Good.
41438	4	Light leaker	do	Clean	Marked	Normal	do	Normal	Do.
41438	18	Cracked	do	do	do	Medium position	do	do	Do.
41438	53	Whole	do	Dirty	do	Settled	do	do	Stale.
41505	38	Cracked	Brown	Stained	do	do	do	do	Good.
41505	50	Whole	do	Clean	do	Below meridian line	do	do	Do.
41506	64	do	White	do	do	do	Deep opalescent	do	Do.
41509	47	Cracked	Brown	do	do	do	Thin	do	Do.
41509	52	do	do	do	Slight	Normal	do	do	Do.
41594	1	Whole	do	do	Marked	Medium position	do	do	Do.
41594	56	Blind check	White	Stained	do	do	do	do	Strong.
41645	24	Cracked	Brown	Clean	Slight	Invisible	do	do	Doubtful sour.
41645	33	do	do	do	do	Normal	Turbid	do	Good.

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[1] As no air-cell was visible the degree of shrinkage could not be determined by candling.

Contamination of the product during manufacture was minimized. The rooms in which the eggs were broken were lined with concrete, the walls were enameled in white, and all the windows were kept closed so that dust could not enter. As an additional precaution the windows were at least triple paned for insulation. All utensils were frequently washed and sterilized and clean apparatus was substituted during breaking whenever any utensil was contaminated by a bad egg. The two principal extraneous sources of bacteria which could not be controlled entirely were the shells of the eggs and the fingers of the breaker. By washing the hands after breaking a bad egg, and by frequently drying the fingers on tissue paper, the number of bacteria derived from these sources was greatly minimized.

The presence of bacteria in commercial frozen and desiccated eggs is due to two causes, namely, contamination during preparation and the quality of the raw material used. In Department Bulletin 224 it was shown that improperly cleaned utensils and faulty manipulation of the egg during breaking contributed many bacteria to the product during the process of preparation. In Department Bulletins 51 and 224, and in the present paper, it has been shown that the bacterial count of the finished product decreases in proportion to the quality of the eggs used.

TABLE XI.—*Laboratory findings in composite samples of individual eggs graded as good.*

Sample No.	Number of eggs in sample.	Number of eggs in sample contributing bacteria.[1]	Bacteria per gram on plain agar incubated at—		Gas-producing bacteria per gram in lactose bile.	Eggs containing gas-producing bacteria.	Ammoniacal nitrogen.		Moisture.
			20° C.	37° C.			Wet basis.	Dry basis.	
							P. ct.	*P. ct.*	*P. ct.*
41142	69	0	Less than 100	Less than 100	Less than 100	0	0.0019	....	......
41143	72	0	Less than 10	Less than 10	0	0	.0013	0.0048	72.87
41144	68	1	190	Less than 10	0	1	.0015	.0055	72.96
41145	67	0	650	550	100	0	.0024	.0087	72.45
41146	68	2	600	Less than 100	Less than 100	1	.0018	.0067	72.96
41147	39	1	Less than 100	Less than 100	0	0	.0015	.0057	73.21
41148	72	1	600,000	490,000	0	0	.0022	....	......
41149	67	14	13,000,000	10,000,000	1,000	7	.0018	.0066	72.64
41161	66	0	130,000	98,000	....	0	.0018	.0074	75.59
41164	68	2	410	340	0	1	....	....	73.34
41167	64	1	55,000	37,000	0	0	....	....	......
41169	65	3	7,500,000	8,100,000	10,000	1	.0011	.0040	72.34
41175	58	8	19,000	19,000	1,000	1	.0021	.0076	72.22
41178	65	2	65,000	58,000	0	1	.0018	.0065	72.34
41180	63	10	3,200,000	350,000	0	3	.0021	.0076	72.28
41182	59	6	1,200,000	13,000	0	0	.0024	.0089	73.11
41185	69	3	1,700	1,000	100	4	.0022	....	......
41189	68	3	40,000	50,000	Less than 100	....	.0018	.0067	73.25
41192	55	55	....	....	....	23	.0020	.0076	73.69
41316	60	5	Less than 1,000	Less than 1,000	10	1	.0015	.0055	72.70
41435	62	5	52,000	53,000	10,000	3	.0022	.0081	72.82
41438	60	5	2,400,000	2,200,000	500,000	4	.0022	.0080	72.38
41505	65	5	410,000	430,000	0	2	.0021	....	......
41506	69	6	3,500	1,000	1,000	2	.0017	.0063	73.17
41509	69	4	140,000	170,000	0	1	.0020	.0074	72.85
41551	70	9	1,100	1,100	0	0	.0014	.0052	73.13
41594	69	7	3,100,000	550	0	0	....	....	......
41598	71	15	17,000	400	0	0	.0021	.0074	71.69
41645	64	52	14,000,000	10,000,000	0	0	.0015	.0054	72.05

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[1] The bacterial counts of these eggs are given in Table IX.

Other conditions being equal, eggs with cracked and leaking shells give a product with a higher bacterial count than do eggs with shells that are sound, even though dirty. Frozen or dried eggs made from summer and fall breaking stock have fewer bacteria than similar products made from spring breaking stock. The breaking of eggs as near the source of production as possible results in the presence of fewer bacteria in products prepared during the warm portion of the season.

TABLE XII.—*General summary of laboratory results on commercial samples of frozen egg taken in three houses during 1912.*[1]

I. BACTERIOLOGICAL RESULTS.

Description of sample.	Number of samples.	Percentage of samples with counts over 5,000,000 per gram.	Number of organisms per gram.		
			Average.	Minimum.	Maximum.
Liquid eggs:					
Whites	39	2.6	[2] 350,000	100	7,500,000
Yolks	54	5.56	[3] 530,000	200	7,500,000
Whole eggs	47	21.28	2,700,000	340,000	11,000,000
Mixed eggs from D house	46	....	1,000,000	5,100	3,300,000
Mixed eggs from F house	12	8.33	1,700,000	470,000	6,800,000
Leaking eggs	53	5.88	1,300,000	500	6,000,000
Soft eggs	13	46.14	20,000,000	130,000	80,000,000

II. CHEMICAL RESULTS.

Description of sample.	Number of samples.	Percentage of ammoniacal nitrogen.						Percentage of moisture.		
		Wet basis.			Dry basis.					
		Average.	Minimum.	Maximum.	Average.	Minimum.	Maximum.	Average.	Minimum	Maximum.
Whites	13	0.0004	0.0002	0.0006	0.0031	0.0016	0.0049	87.37	86.96	88.31
Yolks	23	.0032	.0024	.0045	.0076	.0054	.0103	57.88	53.64	64.06
Whole eggs	43	.0021	.0016	.0024	.0074	.0054	.0087	72.33	70.23	74.17
Mixed eggs from D house	34	.0020	.0014	.0025	.0067	.0046	.0082	68.88	68.33	71.43
Mixed eggs from F house	10	.0023	.0017	.0027	.0071	.0053	.0082	68.06	67.00	70.81
Leaking eggs	37	.0020	.0013	.0028	.0065	.0047	.0080	69.63	64.12	72.83
Soft eggs	11	.0023	.0018	.0031	.0080	.0066	.0098	71.24	67.04	72.99

[1] U. S. Dept. Agr. Bul. 224, p. 20.
[2] One sample with an exceptionally high count not included in this average.
[3] Three samples with exceptionally high counts not included in this average.

EGGS REJECTED DURING GRADING.

EGGS WITH UNDESIRABLE ODOR.

The important part which the sense of smell plays in the grading of breaking stock is shown by the fact that 90 or 52.6 per cent of the rejected eggs, as computed from Table XIII, were eliminated because of an abnormal odor. One-half of the eggs discarded because of odor were musty, and the other half had bad odors of various kinds.

The eggs are classified in Table XIV according to odor. The first group consists of 16 eggs with a bad odor. The laboratory examinations showed that 11 contained bacteria, and 7 of these eggs were heavily contaminated. It is probable that absorption from surrounding materials accounts for the abnormal odor in the other 4 eggs. Operators of cold-storage warehouses have found that eggs stored in the same room with fruits, such as oranges or lemons, absorb the odors of such fruits. When eggs are opened in the breaking plants many varieties of absorbed odors are encountered. Eggs with the odor of kerosene or moth balls are not uncommon. Both materials are used in hen houses to inhibit the development of vermin; one as a spray and the other as a nest egg.

Mold infection very frequently is associated with the presence of both bacteria and molds.[1] It is not unexpected, therefore, to find that fully two-thirds of the eggs with a moldy odor contained bacteria.

It has been found that sour eggs are very heavily contaminated with organisms of the *B. coli* group and that they often contain bacteria in numbers equal to those found in black rots.[2] Only 5 sour eggs were present in the 29 samples. In two instances the egg was graded as a "doubtful sour," as it was not always possible to determine conclusively the dividing line between a sour egg and one that was not sour. This accounts for the sterility of two of the eggs in which it was not certain that the odor was sour.

Considerable care is exercised in the cooperating plants in the grading of eggs with abnormal odors. All eggs, even if they appear sound, are smelled carefully, and if there is any doubt as to whether the odor is due to absorption or spoilage, the questionable egg is discarded.

The musty egg has a peculiarly characteristic odor and taste. In some cases its odor resembles that of old fillers and flats, in others that of certain kinds of weeds or of spoiling hay or chaff, and in still others the odor of sprouting potatoes. As its condition can not be seen by the candle, a musty egg must be detected by its odor out of the shell. Its odor can not always be expelled by cooking. The possible presence of such an egg in breaking stock and the unfortunate results which are likely to occur if it is present in cake or cookie dough made egg breakers realize that eggs must be graded out of the shell as well as by the candle.

Egg handlers frequently do not distinguish between moldy and musty eggs, although the two are distinctly different. The moldy egg is caused by the growth of molds in the egg substance and has an odor characteristic of damp cellars. The musty egg usually is normal in appearance, in fact it frequently resembles a perfectly fresh egg. Occasionally, however, a musty egg with a green white is encountered.

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[1] U. S. Dept. Agr. Bul. 51, pp. 33-38, 46.

[2] U. S. Dept. Agr. Bul. 51, pp. 61-64.

A striking feature of the bacteriological study of musty eggs, excluding those with green whites, is their sterility. Of the 45 musty eggs examined, only three, as shown in Table XIII, contained bacteria. One had 350 organisms, and the other two had 200,000 and 150,000, respectively. The latter two eggs were from sample 41,192, which consisted entirely of eggs showing bacteria. The ammoniacal nitrogen found in musty eggs is not excessive.[1]

Most of the musty eggs were from samples procured in the spring. Sample 41147, which contained a large number of musty eggs, was purchased from a grocery store located in one of the poorer sections of a large city. The eggs had clean brown shells and showed practically no shrinkage on candling. The shells, however, did not have the bloom characteristic of fresh eggs, but had rather the appearance of having been washed.

The most rational theory advanced by the trade regarding the cause of musty eggs is that it may be due to absorption from surrounding materials. If the musty odor is the result of such absorption, it is difficult to explain why it does not become weaker as the egg ages in the shell or in the frozen state; also why the odor in cake or confectionery does not always disappear in baking. Other types of odors do not remain with such persistence. The cause of musty eggs is still unknown.

SOFT EGGS.

Soft eggs represent a transition stage between edible and inedible eggs. If the yolk breaks or is found to be broken when the egg is opened, it is necessary to determine whether or not the egg is fit for food. An egg with simply a ruptured vitelline membrane is not rejected, but if other signs of deterioration, such as whitish streaks in the yolk or a muddy white, are present, it is not considered edible. (See Plate IV.) Sometimes it is found that the yolk of an egg appears very weak before the candle and, on breaking, its outline is practically lost because the yolk material has so quickly intermingled with the white. This type of egg, shown in Plate V, is called by the industry a "runny egg" and is discarded. The soft eggs with the whitish streaks in the yolk and the "runny eggs" very closely approximate the degree of physical deterioration found in mixed rots. Soft eggs sometimes have a sour odor, in which case they are heavily infected with bacteria.[2]

There were 447 soft eggs in the eggs under observation. Of these, 0.7 per cent were found to be sufficiently deteriorated to warrant their exclusion from food products. About 20 per cent of these rejected eggs showed infection.

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[1] Unpublished results.

[2] U. S. Dept. Agr. Bul. 51, p. 61.

Soft eggs found when commercially separating eggs into white and yolk usually contain more bacteria and more ammoniacal nitrogen than do edible frozen whole eggs, as may be seen from Table XII, which summarizes the laboratory findings in commercial products.

The guiding principle to be followed in the grading of soft eggs is to reject every egg that has an odor or a yolk which shows any signs of deterioration other than the rupture of the vitelline membrane.

EGGS WITH GREEN WHITES.

Eggs with green whites constituted 10.5 per cent of the rejected eggs, and 66.6 per cent of these were seriously contaminated. These results are in agreement with those obtained in a more exhaustive study of this type of egg.[1] The six sterile eggs in the table were eggs in which the opalescence characteristic of fresh whites was confused with the "beginning green" of a green white egg.

WHITE AND MIXED ROTS.

White and mixed rots, or eggs with the yolk partially or entirely mixed with the white, are advanced forms of the soft egg. These eggs are generally recognizable before the candle. Only 19 passed the candlers at the commission house into the experimental samples. They showed much more infection than did the soft eggs.[2]

TABLE XIII.—*Eggs rejected during grading.*

I. VARIATION IN BACTERIAL CONTENT.

Description of sample.	Number of bacteria per cc.														Total number of eggs.
	0 to 100		101 to 1,000		1,001 to 10,000		10,001 to 50,000		50,001 to 100,000		100,001 to 500,000		Over 500,000		
	Number of eggs.	Per cent.	Number of eggs.	Per cent.	Number of eggs.	Per cent.	Number of eggs.	Per cent.	Number of eggs.	Per cent.	Number of eggs.	Per cent.	Number of eggs.	Per cent.	
Eggs with abnormal odor, not musty	21	46.7			1	2.2	2	4.4	1	2.2	7	15.6	13	28.9	45
Musty eggs	42	93.3	1	2.2							2	4.5			45
Soft eggs	26	81.3	2	6.3			1	3.1					3	9.4	32
Eggs with green whites	6	33.3											12	66.7	18
Mixed rots	6	54.5			2	18.2			1	9.1	1	9.1	1	9.1	11
White rots	6	75.0											2	25.0	8
Eggs with adherent yolks	2	66.7	1	33.3											3
Miscellaneous	9	100.0													9
Total	118	69.0	4	2.3	3	1.8	3	1.8	2	1.2	10	5.8	31	18.1	171

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[1] U. S. Dept. Agr. Bul. 51, pp. 57–61.

[2] The results of other examinations of white and mixed rots are given in U. S. Dept. Agr. Bul. 51, pp. 29, 30, 53, 54.

TABLE XIII.—*Eggs rejected during grading*—Continued.

II. PERCENTAGE OF EGGS CONTAINING GAS-PRODUCING BACTERIA.

Description of sample.	Total number.	Number examined.	Number of eggs containing gas-producing bacteria.	Percentage of discards containing gas-producing bacteria.
Eggs with abnormal odor, not musty	45	42	6	14.3
Musty eggs	45	45	0	0
Soft eggs	32	32	0	0
Eggs with green whites	18	18	4	22.2
Mixed rots	11	10	2	20.0
White rots	8	8	2	25.0
Eggs with adherent yolks	3	3	0	0
Miscellaneous	9	9	0	0
Total	171	167	14	8.4

TABLE XIV.—*Summary of bacterial findings in eggs with abnormal odors.*

Kind of odor.	Number examined.	Number positive.	Per cent positive.	Number with over 500,000 bacteria.	Per cent with over 500,000 bacteria.
Unclassified bad	16	11	68.8	7	43.8
Moldy	6	4	66.7	3	50.0
Sour	5	3	60.0	2	40.0
Very strong	17	6	35.3	1	5.9
Musty	45	3	6.7	0	0
Coal tar	1	0	0	0	0

SUMMARY.

1. Despite careful candling a small number of breaking-stock eggs contain bacteria, particularly during the summer and fall months. The percentage of eggs containing *B. coli* is markedly lower than the total percentage of eggs harboring bacteria.

2. There is a progressive rise in the percentage of bacterial contamination through the following series: Clean whole eggs, dirty whole eggs, clean cracked eggs, dirty cracked eggs, clean leaking eggs, and dirty leaking eggs.

3. Eggs with weak yolks show a greater degree of bacterial contamination than do eggs with firm yolks.

4. A settled yolk is not *per se* an evidence of the presence of bacteria.

5. Eggs with adherent yolks and eggs with addled contents are not only abnormal in appearance, but, in many instances, are harborers of bacteria. They should not be included in food products.

6. Some eggs containing bacteria can not be recognized by their appearance or odor. A very large percentage of eggs containing bacteria, particularly those with high bacterial content, can, however, be recognized by the senses.

7. Despite careful grading out of the shell, the percentage of eggs containing bacteria in mixtures prepared for freezing or drying may average 12 per cent of the eggs used.

8. The number of bacteria per gram in composite products prepared for freezing or drying, due to unrecognized infected eggs, may vary from a few hundred to several million. Some but not all the *B. coli* in the composite mixtures prepared commercially are derived from the raw material.

9. A "weak egg" which has decomposed to such an extent that it has a muddy white or a whitish streak in the yolk should be discarded as unfit for food purposes, even though it may show no bacteria, as the absence of bacteria does not in itself signify that an egg is edible.

10. The musty egg does not usually contain bacteria, neither is it decomposed as judged by the appearance or the quantity of loosely bound nitrogen present. The cause of the musty egg is not known.

11. The production of frozen and dried egg products of good quality requires, first of all, good raw material, and, subsequently, care in grading the eggs both before the candle and out of the shell.

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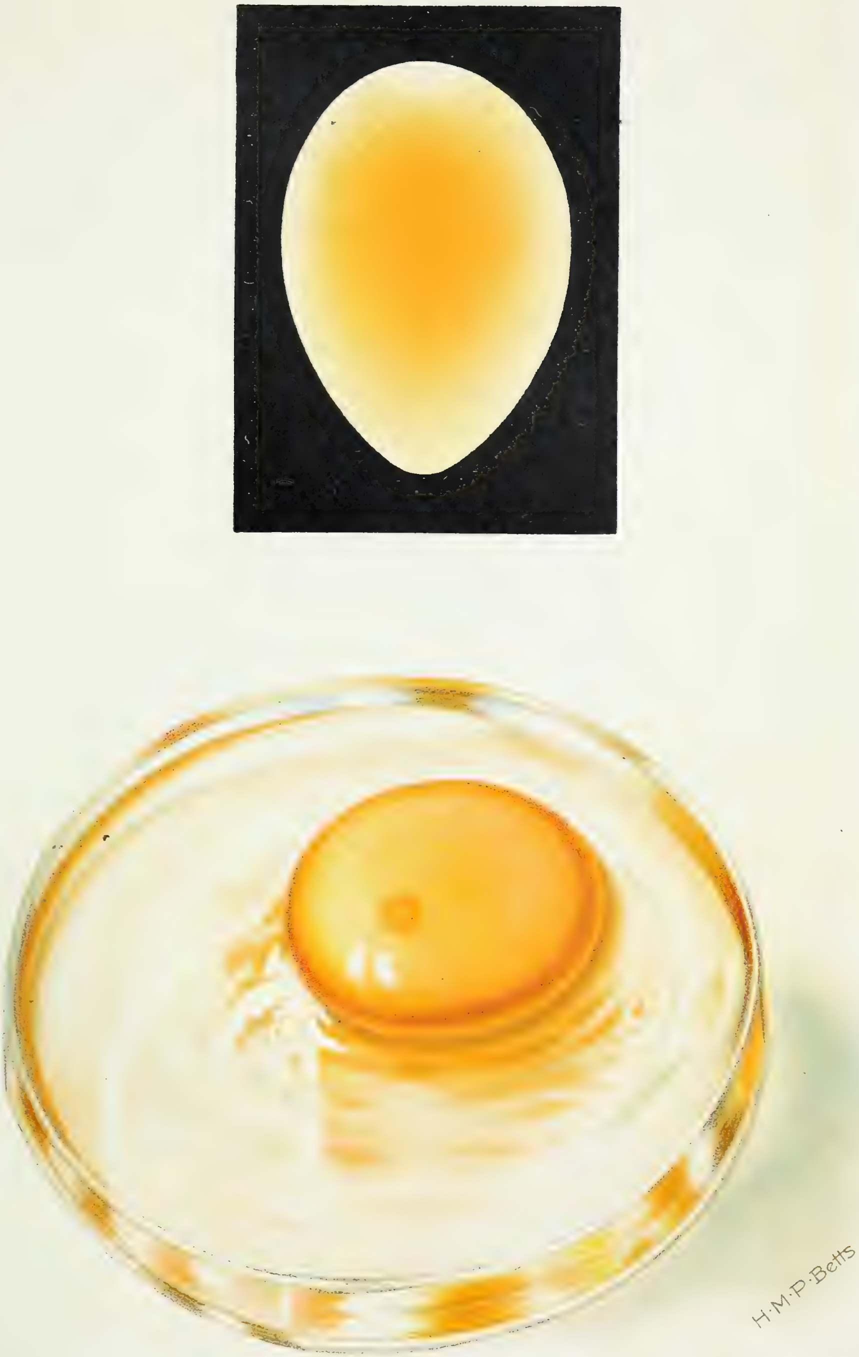

A FRESH EGG BEFORE THE CANDLE AND OUT OF THE SHELL

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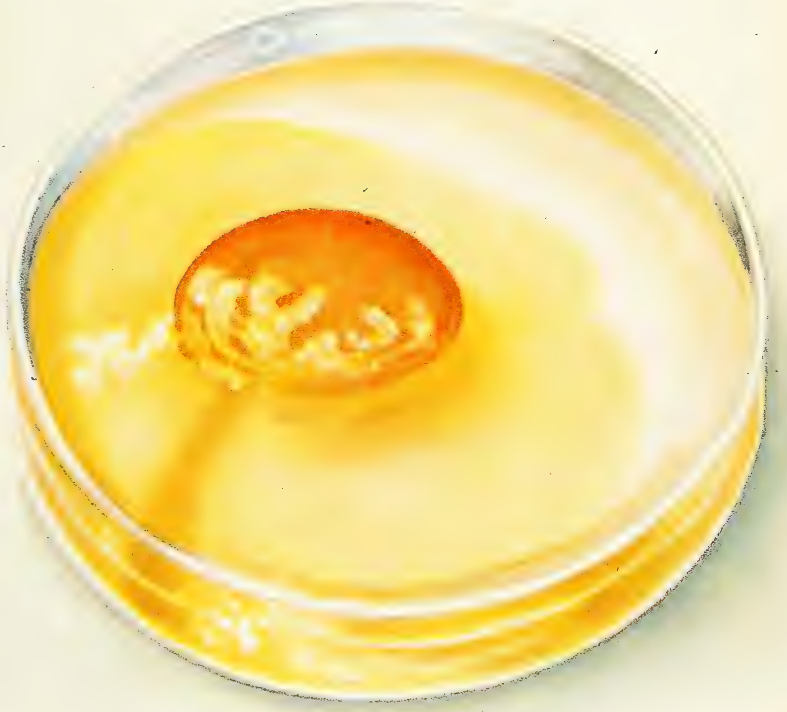
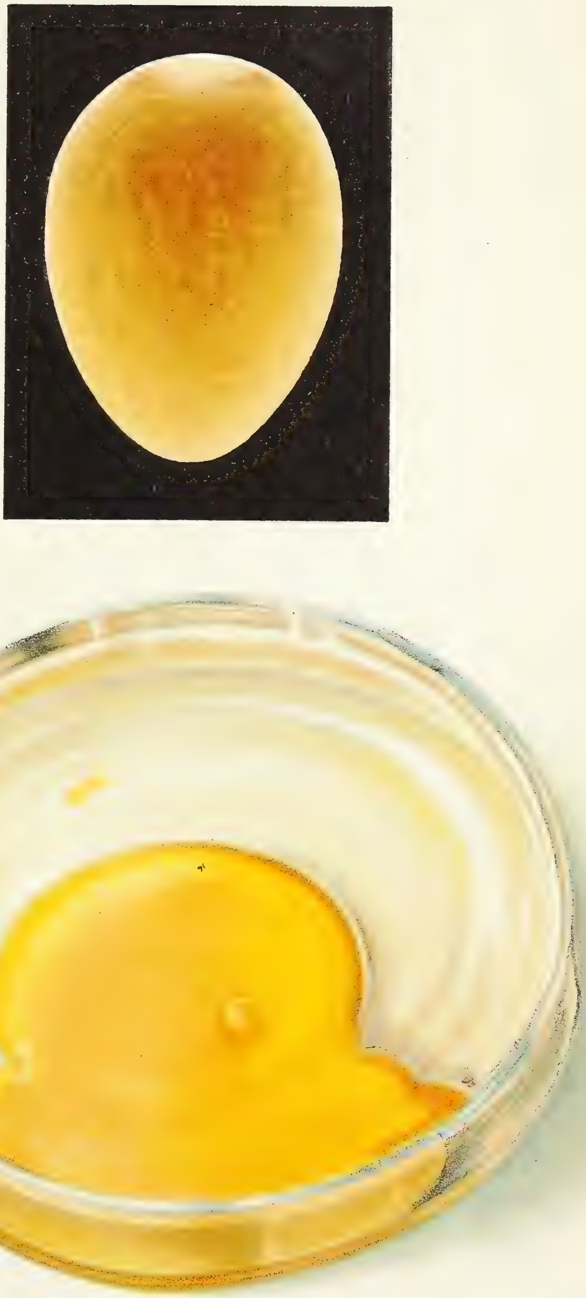
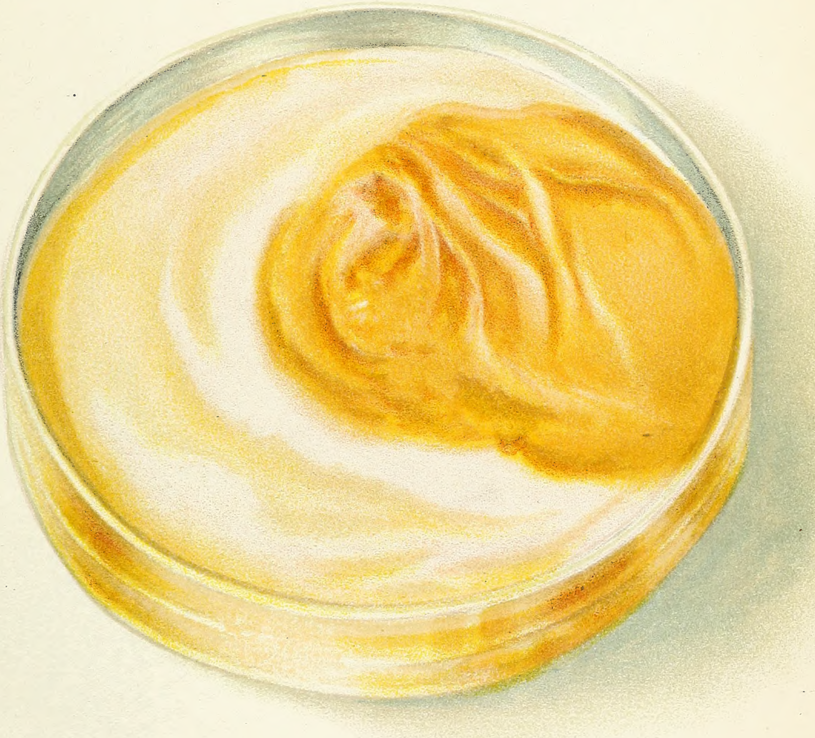
7



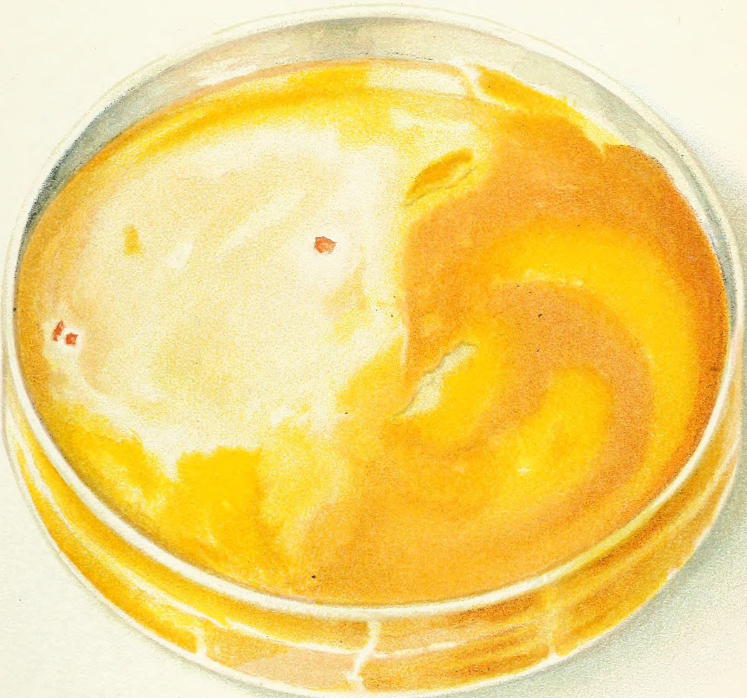
EGG OUT OF THE SHELL, SHOWING YOLK SEEPING INTO THICK WHITE



Egg with Soft Yolk, Before the Candle and Out of the Shell



SOFT EGG OUT OF THE SHELL, SHOWING WHITE STREAKS IN YOLK.



SOFT EGG OUT OF THE SHELL, SHOWING SPREADING YOLK